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SPECTRUM MANAGEMENT

by

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Strategic Issues in National Spectrum Management

by

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ABSTRACT

The demand for allocations and assignments in the radio frequency spectrum continues to grow in the United States and internationally. The unique properties of the spectrum combined with this growing demand have created a significant managment challenge for the Federal Goverment. As a principal user of the spectrum, the military services are especially dependent upon the national spectrum management processes. Effective command and control of forces and optimum use of electronic sensory, navigation, and weapons systems are all contingent upon the ability to utilize the radio frequency spectrum.

It is the responsibility of the national spectrum management process to encourage maximum utilization of the spectrum while maintaining electromagnetic compatibility. The importance of the spectrum to the military makes it imperative that the services develop a comprehensive strategy to protect the resources they currently have and help them to compete successfully for future requirements. This strategy must involve the development of clear national policy objectives relating to the spectrum, must contain guidance for improving the utilization of existing assignments, and must provide direction to new technologies.

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While it has been just over one century since Heinrich Hertz discovered electromagnetic radiation (1887), it seems unlikely that even the most prescient of his generation could have predicted the degree to which all nations have become dependent upon the electromagnetic spectrum. In the United States we rely on electromagnetic waves for everything from remotely opening a garage door to communicating with our strategic military forces abroad. There is a seemingly endless number of applications using the spectrum, and to exploit them one must possess a knowledge of just what the spectrum is and what restrictions exist regarding its use.

A. PROPERTIES OF THE SPECTRUM

Even the most basic concepts involved in understanding how electromagnetic waves propagate tend to conjure up something mystical. This thesis is not designed to explain the theories of Maxwell, Hertz, or any of the other pioneers in the field of electromagnetics. What is necessary, though, is a clear understanding of what the spectrum can support in terms of communications and information transfer.

It has long been understood that the spectrum is unique among natural resources. These differences have resulted in much of the pressure to regulate the spectrum. Some principles that apply are

- The spectrum is limited, both in terms of the technology we have to exploit it and the associated economic factors.
- The spectrum is inelastic. This resource has dimensions of time, space and frequency. No two similar signals can occupy the same geographic space at the same time without creating interference. Each signal must use these dimensions differently to establish a clear path from the transmitter to the receiver.
- The radio frequency spectrum does not recognize national boundaries nor regulatory edicts. This means that at both the national and the international level there must be a substantial degree of coordination and cooperation to limit interference.

- The spectrum is free. While there are costs associated with the regulatory processes that govern use of the spectrum, the United States has long recognized the spectrum as a public resource to be shared by those with a legitimate need who are willing to abide by all regulatory guidelines. This has been one factor in increasing demand from both the Government and the private sector, but it has also reduced the motivation to achieve more efficient, high-value uses for the spectrum.
- The spectrum is not exhausted through use. [Ref. 1: pp. A-4 - A-7]

In an effort to establish some descriptors for the spectrum that are useful in working with it, waves are typically described in terms of frequency and wavelength. The radio frequency spectrum, just one portion of the entire electromagnetic spectrum, ranges in frequencies from a few thousand cycles per second (Kilohertz) to 400 billion cycles per second (Gigahertz). The current allocation table for the United States covers from nine kilohertz (wavelength of approximately 33.31 kilometers) to 300 gigahertz (wavelength of approximately 1 millimeter). These different frequencies and their associated wavelengths possess different propagation characteristics, and for ease of classification frequencies are grouped in ranges where similar characteristics apply. These characteristics also determine what applications can be effectively implemented in certain regions of the spectrum. Table 1 shows the common frequency bands with some of the applications they support.

B. THE NEED FOR SPECTRUM MANAGEMENT

The evaluation of any communication requirement should include the economic and technical concerns as well as the desired propagation characteristics in deciding where to operate within the usable spectrum. Translated into more practical language, this means that the demand for spectrum resources will never be uniformly distributed across the 300 billion different integer frequencies available in the allocated spectrum. Crowding occurs when many users desire to operate within a small portion of the spectrum. In spite of the sheer size of the spectrum, this has become a very real problem. In the mid-1970's, virtually all of the practical applications were utilizing only one and one-third percent of the allocated radio frequency spectrum. Experimental work accounted for work in roughly ten percent of the remaining spectrum.

Table 1. RADIO FREQUENCY BANDS

Frequencies	*Band*	*Typical Uses*
30-300 GHz	Extremely High Frequencies (EHF)	Microwave relay; space research: radar: radionavigation
3-30 GHz	Super High Frequencies (SHF)	Microwave relay: satellite telemetry and communication: aeronautical radionavigation, meteorological aids
300-3000 MHz	Ultra High Frequencies (UHF)	Short-range communications: microwave relay; UHF television: weather satellites: space tracking and telemtery
30-300 MHz	Very High Frequencies (VHF)	Short-range line-of-sight communication; VHF television; FM broadcast; space tacking and telemetry; aeronautical distress: worldwide radionavigation
3-30 MHz	High Frequencies (HF)	Medium- and long-range communication: international broadcasting: international point-point. air-ground. ship-shore
300-3000 KHz	Medium Frequencies (MF)	Medium- and short-range communication: AM broadcast; radionavigation: marine radiophone: Loran; international distress, disaster
30-300 KHz	Low Frequencies (LF)	Long- and medium-range point-point communication, radionavigation aids: aeronautical mobile
3-30 KHz	Very Low Frequencies (VLF)	Very long-range point-point communication
<3 KHz	Extremely Low Frequencies (ELF)	Long-range communication that requires seawater penetration
KHz - Kilohertz (thousands of cycles per second) MHz - Megahertz (millions of cycles per second) GHz - Gigahertz (billions of cycles per second)		

Thus, nearly 90 percent of the allocated spectrum was unused [Ref. 1: p. A-4]. This underscores the concept that the usable spectrum is very different from the radio frequency spectrum. There are two ways to effectively deal with the problems of crowding:

- Utilizing advances in technology we can increase the size of the usable spectrum.
- By regulating the use of the spectrum, we can limit interference.

Historically users have depended heavily on both, but have relied on advancing technology to limit the need for greater regulation. In practice, they must be considered as complementary means of better managing the spectrum.

C. THE GOALS OF SPECTRUM MANAGEMENT

While the need to regulate the spectrum is widely accepted, the objectives and processes are less easily defined. They must be derived from national goals and objectives that are supported directly or indirectly by the spectrum. In the mid-1970's the Office of Telecommunications Policy stated the national objectives for the use of the spectrum were

- to enhance the conduct of foreign affairs
- to serve the national security and defense
- to safeguard life and property
- to support crime prevention and law enforcement
- to support the national and international transportation system
- to foster the conservation of national resources
- to provide for the national and international dissemination of educational, general, and public interest information and entertainment
- to make available rapid, efficient, nationwide and worldwide radiocommunication services
- to stimulate social progress
- to improve the well being of man. [Ref. 1: pp. D-11 - D-12]

These same objectives appear in the current manual of regulations and procedures that govern spectrum management [Ref. 2]. They must be translated into a second set of objectives that can be applied to manage the radio

frequency spectrum. This is a difficult task, but over time, the prime objectives of centralized frequency management have evolved into maximizing the use of the spectrum, minimizing the interference in its use, and maximizing information through a channel per unit time.

D. SPECTRUM MANAGEMENT PROCESSES

The problem that presents itself is best summed up by author Harvey Levin, who wrote,

> "Maximum use" or "full occupancy" as such may run directly counter to the minimization of interference, which is best achieved, technically, through no use at all. [Ref. 3: p. 65]

This inherent problem of balancing opposing objectives proves to be the basis for most of our modern regulation. The question that arises is, "What activities and processes will be needed to achieve this balance?"

In general terms, the management of the spectrum encompasses three basic tasks: allocation, allotment, and assignment. The National Telecommunications and Information Administration defines these to be:

- Allocation - Entry in the Table of Frequency Allocations of a frequency band for the purpose of its use by one or more radiocommunications services. This does not imply any specific user. only those services that are authorized within a band.
- Allotment - Entry of a designated frequency channel in an agreed plan, adopted by a component Conference. for use by one or more administrations for a radiocommunication service in one or more geographic regions. Thus, allotments are used to identify the allocated services that apply to a given band in some geographic area.
- Assignment - Authorization given by an administration for a radio station to use a given frequency or frequency channel. This implies that the user has some property rights or control over the frequency to the exclusion of others. [Ref. 2: p. 6-2]

A fourth term that is often used when discussing spectrum management is apportionment. This is used typically to describe the division of spectrum between the government and the private sector.

Now that there is a good understanding of what management tasks the "regulator" is responsible for, an investigation of how these decisions are

made can begin. Clearly structure has an impact on these decisions, and the structure of the Federal Government's regulatory bodies will be addressed in Chapter Four. For the purposes of this chapter, the criteria that the regulatory bodies are required or obliged to use in the execution of their duties will only be briefly identified.

E. NATIONAL PHILOSPHY

The foundation of the basic philosophy that guides national spectrum management is located in the Communications Act of 1934. One of the principle reasons this law was enacted was to

> make available, as far as possible, to all the people of the United States a rapid, efficient, Nation-wide and world-wide wire and radio communication service, with adequate facilities at reasonable charges, for the purpose of promoting safety of life and property through the use of wire and radio communication [Ref. 4].

This has come to be known as the concept of universal service, and has been a major force behind much of our current telecommunications policy and regulation. As a decision criterion, however, it is fundamentally flawed. In a country where the private sector is responsible for most of the communication systems used by the public, it fails to recognize the significance that economic factors will have on the providers of these services. In many cases, the idea of universal service at reasonable charges may be contrary to existing technology and procedures; and, even if not, these concepts are imprecise and open to wide interpretation.

A second basic mandate of the Act was that any spectrum management decision, whether related to allocation, allotment or assignment must be weighed as to the "public interest, convenience or necessity." This standard, nebulous language tends to create more questions than it answers. When this phrase was included in previous legislation (1927), the responsible regulatory agency was soundly criticized for not issuing a precise definition. As time has passed, subsequent legislation, regulation, and litigation have all served to continually redefine what the public interest is and how it can best be served [Ref. 5: pp. 43-44].

F. RESEARCH AREA

This thesis will look at the structure and processes involved in spectrum management in the United States to answer the following questions

- How effective is the Federal Government at management of the spectrum? We will look at the historical development of national spectrum management and the current regulatory environment. While the focus of this research will be on the national level, certainly the very nature of the spectrum demands that international considerations be addressed to some extent. They will be included to show how important developments on the international scene influenced national policy and regulation.
- What alternative regulatory schemes exist? Even if the Government does a good job, there is the inherent assumption in a market economy that a more efficient distribution of goods occurs when market forces are allowed to determine that distribution. In the United States, the Government's role and responsibility in regulating resources is always being reexamined.
- What does technology hold for the spectrum? While technology has been a significant factor in opening up more of the spectrum, these changes have also served to increase demand. We must assess the state of technology and how it supports the national goals and objectives to determine whether technology will continue to let us use the spectrum more efficiently.
- Lastly, what management strategy will best assist the Armed Forces at the national level in obtaining and retaining the spectrum resources required to support our forces and our commitments? This will require an assessment of the forces that exert the most influence on spectrum management processes, to determine if there is pressure to bring about change in the status quo.

Additionally there will be some consideration of the international forces that impact on our national spectrum management processes. All of this must result in a determination as to what policies and positions the Armed Forces can adopt to best defend their interests.

II. HISTORICAL BACKGROUND OF SPECTRUM MANAGEMENT

A. INTRODUCTION

Once Marconi had received a patent for the radiotelegraph in 1896 and had tested it successfully, it was evident that radio communication would become a necessity in the maritime environment. The United States immediately began to equip naval ships and to construct shore stations. In 1904, the Board on Wireless Telegraphy reported to President Roosevelt that 24 ships were equipped with radiotelegraph and that ten more ships were in the process of being outfitted. Over thirty coast stations were operating with an eventual total of 200 afloat and on-shore stations planned [Ref. 5: p. 6]. It is ironic that, while the Federal Government quickly recognized the importance of radio, there was a total lack of initiative to regulate or control the radio frequency spectrum.

B. EARLY DEVELOPMENTS

The First International Radio Conference was held in Berlin in 1903. At the time, the pressing concern to the attendees was how to eliminate the control that the Marconi Company had on international communication.

> Prince Henry of Prussia, brother of the German Kaiser, was returning to Germany, in the S.S. Deutschland, after a visit to the United States. Soon after sailing, he desired to send President Roosevelt a radio message thanking him for the numerous honors and courtesies which had been accorded him. The Deutschland transmitted this message to the Marconi station at Nantucket, but that station refused to accept it because the ship was fitted with Slaby-Arco radio equipment. The irate Prince brought the matter to the attention of his brother. Kaiser Wilhelm thereupon instructed his government to initiate action in an attempt to establish international control over radio communication [Ref. 6 : p. 71].

That action resulted in the initial 1903 conference. Nine countries were represented, and although no complete agreement was reached, a protocol was drafted to serve as the basis for future international agreement. All of the delegates to the conference returned home having agreed to submit the protocol to their respective governments for examination [Ref. 5: p. 7]. The inability to

agree upon a convention resulted from reservations by Great Britain and Italy, the two countries where Marconi's interests were the strongest [Ref. 7: p. 17].

A second International Radio Conference met in Berlin in 1906. This was attended by a total of 28 countries, including all nine nations involved in the initial conference. The Convention that was adopted marked the beginning of international regulation of the radio frequency spectrum. Major provisions of the convention were

- The requirement for acceptance of messages by all coastal stations and ships regardless of equipment used.
- Priority for distress calls from ships.
- Establishment of an International Bureau to gather information about systems in use and coastal stations.
- Establishment of tariffs for international radio communications.
- 500 KHz and 1000 KHz were estabished as common calling frequencies. [Ref. 5: pp. 7-8]

These new provisions went into effect in 1908 with the exception of the United States which failed to ratify the convention until 1912. The ratification hearings had begun before the Senate Committee on Foreign Relations in January 1908. One of the key opponents to the convention was none other than former Attorney General John W. Griggs, who was then the president of Marconi Wireless Telegraph Company of America [Ref. 6: p. 124]. Although the convention was shelved by Senate Republicans, it was eventually ratified when the United States invitation to the 1912 International Radio Conference was withdrawn by a vote of the other adhering countries. Upon ratification, the invitation was again extended [Ref. 5: p. 9].

Domestic regulation of radio communication and of the radio frequency spectrum began in 1910 with the passage of the Wireless Ship Act. This required passenger vessels (greater than 50 passengers) to have wireless equipment installed and trained operators on board. The Secretary of Commerce was the administrator of the new law. since he was already responsible for domestic maritime law [Ref. 8: p. 4].

The first comprehensive legislation to address radio communication was the Radio Act of 1912. It required all radio stations to obtain a license from the Secretary of Commerce in order to operate. The act was very specific and left the Secretary with no discretionary authority. His function was to minimize interference among stations. The Act did, however, allocate specific frequency bands for government and commercial use. Frequencies above 1500 KHz (the upper end of the AM broadcast band) were allocated to amateur operators as they were considered of little practical use [Ref. 5: p. 10].

C. THE RADIO ACT OF 1927

As time passed in the 1920's, it was apparent that the guidelines of the Radio Act of 1912 were inadequate to effectively manage the radio frequency spectrum. This resulted from significant improvements in technology (the invention of the vacuum tube) and from changes in the private sector (the formation of the Radio Corporation of America). In response to these rapid changes, Secretary of Commerce Herbert Hoover created the Interdepartment Radio Advisory Committee (IRAC) in June 1922. The purpose of the IRAC was to assist in the assignment of frequencies to government users [Ref. 8: p. 9].

In the winter of 1922 the First National Radio Conference was convened to bring together government, manufacturers and broadcasters. Everyone agreed that the government needed to formulate a structured radio policy. The conference declared that "radio should be regulated and controlled by the Federal Government" [Ref. 8: p. 8].

The rapid changes occurring in the broadcast industry created significant concerns in the Congress that new legislation was needed. The three main concerns that they expressed were

- The issue of vested rights in the radio frequency spectrum.
- The criteria for the granting of radio station licenses.
- The fear of monopoly in the radio equipment market. [Ref. 5: p. 21]

Out of these concerns the Radio Act of 1927 was born. It created a five man Federal Radio Commission (FRC), whose first chairman was Admiral W. H. G.

Bullard, USN (Retired). The FRC had been given the authority to grant, renew and revoke radio station licenses [Ref. 8: p. 12]. While not nearly as expansive as the government's current authority, it marked a significant increase in government regulation of the broadcast industry.

In addition to the establishment of the FRC, the Act required the President to assign all government frequencies. This further enhanced the role of the IRAC as an advisor to the President. In 1928 the FRC requested, and was granted, permission to attend IRAC meetings. This marked the beginning of cooperative efforts to resolve frequency allocation problems between the government and the private sector [Ref. 8: p. 13].

During this same time, there was increased pressure for international regulation of the spectrum as well. The first true Table of Frequency Allocation was adopted at the Washington Radio Conference in 1927 by the delegates of the 79 nations attending. The table adopted had actually been developed by the five allied powers as a part of their preparations for the Treaty of Versailles [Ref. 1: p. B-3].

D. THE COMMUNICATIONS ACT OF 1934

The election of Franklin D. Roosevelt in 1932 was an indication that, in the wake of the economic collapse of 1929, the country desired stronger, more centralized leadership. In addition, there was a keen interest in improving accountability within the Executive Branch [Ref. 8: p. 14]. It was against this backdrop that, in 1933, the Secretary of Commerce appointed an Interdepartment Execution Committee to conduct a study of telecommunications management in America. In January 1934, study chairman Daniel Roper presented the group's findings to the Senate Commerce Committee. At the same time, the House Interstate and Foreign Commerce Committee had instructed Dr. W. W. Splawn to conduct a similar study. Both the Roper and Splawn reports were highly critical of how the authority and responsiblity over radio and the spectrum had been dispersed among different committees and agencies [Ref. 8: p. 15].

These two reports provided the momentum needed for Congress to pass the Communications Act of 1934. The most important part of this legislation was the creation of the seven man Federal Communications Commission, with expansive regulatory powers [Ref. 7: p. 21]. The FCC superceded the Federal Radio Commission, and assumed authority over both radio licenses and the telephone and telegraph industries. The IRAC retained its responsibility as the pricipal advisory body to the President regarding the allocation of frequencies to government users. The role of the President was envisioned as one of support. No agency or committee was created to coordinate research and development in telecommunications, to oversee the use of the spectrum, or to serve as the focus of Executive Branch interest in communications [Ref. 9: p. 9-5].

The period from 1934-1940 served as a time to clarify roles and responsibilities between the FCC and the IRAC. In late 1940 an agreement was signed stating

> The Interdepartment Radio Advisory Committee will cooperate with the FCC in giving notice of all proposed actions which would tend to cause interference to non-government station operation, and the Federal Communications Commission (will do the same with the IRAC) [Ref. 10: p. 8.].

The following year, during its twentieth year of existence, the IRAC finally approved a set of bylaws that would govern its activities and procedures [Ref. 8: p. 18].

E. WORLD WAR II

The Second World War place unprecedented demands on the communications capabilities of the country, and even more acutely on the FCC and the IRAC. In 1942, President Roosevelt created the Board of War Communications so that a body existed at the Executive Branch level that could be used to conduct assessments of the nation's communication systems. The members of the Board included

- FCC Chairman, as chair
- Chief Signal Officer of the Army

- Director of Naval Communications
- Assistant Secretary of State in charge of the Division of International Communication
- Assistant Secretary of the Treasury in charge of the Coast Guard

The IRAC was assigned as an advisory committee to the Board [Ref. 8: p.18].

As early as 1943, the IRAC began to deny requests for frequency assignments. The principle concern was that the usable portion of the spectrum had been exhausted. This caused a division between the IRAC, who represented the government's needs, and the FCC, who was obliged to defend commercial interests. The disputes were sufficient to result in a Congressional investigation and with calls for greater clarification of roles and resposiblities in the Executive Branch regarding the management of the radio frequency spectrum [Ref. 8: p. 19].

F. POST WORLD WAR II

The rapid advances in technology during World War II combined with the natural breakdown in international cooperation caused by the war had created disorder in the recording of frequency assignments and a pressing need to address the new portions of the spectrum that were being exploited. An International Radio Conference was convened in 1947 (Atlantic City) to deal with these problems. Many of the member countries of the International Telecommunication Union (ITU) underwent significant changes in their communications capabilities in the nine years that had passed since the previous conference. The three major actions of the Convention that affected frequency allocation were

- The division of the world into three regions, as a part of the Radio Regulations, for the purpose of frequency allocation.
- The Frequency Allocation Board was created.
- The International Frequency Registration Board was created. [Ref. 11: pp. 237-241]

Domestically, the United States was grappling with the need to develop joint policy direction for radio, telephone and telegraph services. In 1946, the

Telecommunications Coordinating Committee was established within the Department of State as an advisory board to the President on telecommunication matters. The TCC proved ineffectual, however, due to its inability to exercise any control over the FCC or the IRAC [Ref. 8: p. 19].

The inability of the TCC to function effectively combined with a failure of the ITU's Provisional Frequency Board to resolve frequency registration problems caused significant pressure to be put on President Truman to create an Executive level agency with the authority to draft telecommunications policy for the government. In 1950, Executive Order 10110 established the President's Communications Policy Board (PCPB). This board was charged with providing the President with a report that evaluated and recommended

- Policies for the most effective use of radio frequencies by governmental and non-governmental agencies and alternative administrative arrangements for the sound effectuation of such policies.
- Policies with respect to international radio and wire communications.
- Guidelines to govern the relationship between government communications and non-government communications.
- Any other such policies that the Board determined to be relevant to their area of study. [Ref. 12: pp. 2-3]

The Board's final report was submitted in 1951, and the first of four general problem areas they identified was

> How shall the United States formulate policies and plans for guidance in reconciling the conflicting interests and needs of Government and private users of spectrum space? [Ref. 12: p. 8]

The PCPB had identified specific problems that fundamentally precluded the effective management of the radio frequency spectrum. The first of these was that both the FCC and the IRAC were inextricably tied to separate, competing user groups. No national policy existed to clarify the dual control that existed over this single resource and to assist in apportioning the spectrum between government and non-government users [Ref. 12: p. 187]. No criteria existed on which to evaluate the conflicting needs that had and would continue to arise. In addition, the TCC was incapable of playing any major role in the

formulation of policy. TCC procedures were based on unanimity, therefore any dissent effectively doomed proposals being considered. The report recommended a reorganization and strengthening of the TCC.

The primary recommendation in the report was for the creation of a three man Telecommunications Advisory Board within the Executive Office of the President. This board would execute the President's responsibilities under the Communications Act of 1934, and would "stimulate and coordinate the formulation and publication of plans and policies..." [Ref. 12: p. 209] One of the first tasks of this new body would be to evaluate the Federal Government's use of frequencies to determine if they supported a demonstrated need. Based upon the recommendations of the report, in October 1951, President Truman established the Office of Telecommunications Advisor and assigned to it those responsibilities recommended by the PCPB.

The next year was marked by the release of a major report entitled *Radio Spectrum Conservation* [Ref. 13], which contained the results of work by the Joint Technical Advisory Committee of the Radio-Television Manufacturer's Association and the Institute of Radio Engineers. While this document dealt primarily with technical concerns about the spectrum, it did contain a proposal for a new way of allocating spectrum aptly entitled Dynamic Conservation. Stated simply, allocations would no longer be considered permanent in nature. The allocation scheme would be designed to "accomodate new services as their value is established and close out or restrict older services as their value wanes" [Ref. 13: p. 177]. As changes in technology allowed spectrum to be used more efficiently, there would be incentives, primarily economic, that would encourage the utilization of newer equipment and procedures. The report did fail to address how the emphasis on a more competitive approach to spectrum allocation and regulation would overcome the political and bureaucratic hurdles necessry to overhaul the existing system.

Less than two years after it was created, the Office of Telecommunications Advisor was abolished when President Eisenhower revoked the original Executive Order. Under a new Order, the responsibilities for telecommunication

plans and policies were assigned to the Director for Defense Mobilization. The Office of Assistant Director for Telecommunications was established within the Office of Defense Mobilization (ODM) to formulate national policy on telecommunication issues [Ref. 8: pp. 32-34]. One of the results of this new structure was that the IRAC now reported directly to the Assistant Secretary in the ODM. This arrangement, combined with the communication demands of supporting troops during the Korean Conflict, created, in the words of Herbert Schiller, a "military takeover" of IRAC [Ref. 14 p. 36]. Increasingly the Department of Defense began to provide greater administrative and financial support to IRAC. In October 1953, FCC membership in the IRAC was ended, and replaced by a new liaison relationship. This further weakened the voice of the private sector in the apportionment of spectrum for government use [Ref. 14 p. 37].

G. THE 1960'S

The increasing influence of the military in the process and execution of spectrum management became even more pronounced during the early 1960's. An appraisal conducted in 1961 concluded that only 30 percent of the spectrum was available to non-goverment users with

> the remaining 70 percent being Government agency controlled, with about 40 percent exclusively Government and totally withdrawn from citizen use. [Ref. 15: p. 168]

While technical and security concerns prevented any precise determination, one estimate by the Government stated that the Armed Forces accounted for about three-fifths of the Government's portion of the radio spectrum [Ref. 16: p. 24].

In February 1962, President Kennedy created the Office of Telecommunication Management within the Office of Emergency Planning (the second generation successor to the ODM). The IRAC was to act in an advisory capacity to the new office. The intent of this change was to centralize control over Government communications. Eighteen months later, the National Communications System (NCS) was established, marking the "formal assumption of

control of all government communication (at least those of a long line nature) by the Department of Defense" [Ref. 14: p. 43]. Facilitating the further militarization of governmental communications was the resignation of the first Director of Telecommunications Management, Irwin Stewart, in 1963. Later that year, concerned by the growing military control over the spectrum, Stewart wrote, "should the military assessment of its communications needs and the best way of meeting them be accepted without question?" [Ref. 17: p. 163] These concerns were not assuaged when President Johnson's nominee to fill the post vacated by Stewart was Lt. General James D. O'Connell, U. S. Army (Retired), a former Chief Signal Officer of the Army [Ref. 14: p. 46].

As the decade passed, there was an increasing interest to reevaluate the current structure and process. On August 14, 1967, President Johnson sent a lengthy message to Congress that covered an array of communications issues, and also advised them that a Task force on Communications Policy was being appointed. One of the major questions they were to study was, "Are we making the best use of the electromagnetic spectrum?" [Ref. 18: p. 8] When the report (known as the Rostow Report) was filed, several problems were identified.

- The block allocation scheme had created systemic sub-optimal allocation and inefficiency.
- The division of government and non-government spectrum resources and management procedures had created inefficiency.
- Spectrum waste was a significant problem.
- Criteria for apportioning spectrum among competing users was unsatisfactory.
- The staff and funding for spectrum management was inadequate. [Ref. 9: pp. 8-19--8-27]

Their general recommendations were

- A greater consideration of economic factors was needed which would result in high-value spectrum uses being substituted for low-value uses.
- More emphasis was needed on spectrum engineering and technical considerations.

- Greater management capabilities and a restructuring of responsibility and authority are required. [Ref. 9: pp. 8-63--8-66]

One specific recommendation made was that a single agency be created within the Executive Branch with overall responsibility for efficient use of the spectrum by all users. It is noteworthy that General O'Connell filed a lengthy dissent to the report, but he did not take exception to any of the recommendations made regarding spectrum management [Ref. 19: p. 10]. Having been presented to President Johnson shortly after a Republican victory in the Presidential elections, the report suffered from poor timing and was never officially released.

H. THE NIXON YEARS

Shortly after taking office, President Nixon appointed Peter M. Flanigan and Maurice A. Stans (his Secretary of Commerce) to be his key men regarding telecommunications management. Stans clearly wanted to exercise control over allocation and apportionment. He argued that the Rostow Report supported his position as did an additional study by the Bureau of the Budget [Ref. 8: pp. 103-107]. The strongest point that Stans had in his favor was that every major study since the PCPB Report in 1951 had recommended that a single agency be responsible for spectrum management. This "power play" by Stans was effectively countered by Secretary of Defense Melvin Laird, who argued that the FCC, having been created by Congress as an independent regulatory agency, could not become a part of the Executive Branch without violating the Communications Act of 1934. The Stans proposal represents the last attempt to consolidate all spectrum management within one agency.

In July 1969, the Government Accounting Office released a report that amounted to a report card for the NCS. It recommended a strengthening of the Office of Telecommunications Management; first by moving it directly into the Executive Office of the President, and secondly by establishing it as the Executive Agent for the NCS [Ref. 20]. By September of that year, the Director of Telecommunications Management had written to the President requesting an end to all the studies which were creating confusion and delaying important

decisions. General O'Connell recommended a continuation of the status quo [Ref. 21]. He was mandatorily retired due to age within a month of writing his letter, and the internal machinations at the White House continued [Ref. 8: p. 117].

Finally in April of 1970, the Office of Telecommunications Policy (OTP) was created within the Executive Branch. The responsibilities of the OTP included

- To act as the President's primary advisor on telecommunications policy, helping in the formulation of domestic and international policy.
- To formulate policies and to coordinate the Federal Government's communications systems.
- To act as a clear voice from the Executive Branch in dealing with the Congress and the FCC on areas of mutual interest or concern. [Ref. 22: p. 20]

For the first time, the individual responsible for the formulation of spectrum management policy would report directly to the President. The hope was that through a centralized agency, the government would be able to develop more effective policy and to simplify the regulatory process. Whether this would have happened is a question that need not be answered, for within the decade OTP would be abolished.

I. THE NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

Shortly after taking office, President Carter introduced Reorganization Plan No. 1, which was approved by Congress, authorizing the establishment of the Assistant Secretary of Commerce for Communications and Information. This was followed by the creation of the National Telecommunications and Information Administration (NTIA) within the Department of Commerce. This new agency would combine the OTP and the Department of Commerce's Office of Telecommunications, and would report to the Secretary of Commerce [Ref. 23: p. 1]. The IRAC would now report to the NTIA, and in fact the IRAC chair would be filled by a representative from NTIA. Critics charged that this new administration was relegating spectrum management to a less important role, and that this would most likely lead to failure.

The NTIA is still in existence today, and is charged with the management of the radio frequency spectrum for the Federal Government. The agency's organization and the current administrative structure will be discussed in the next chapter.

J. SUMMARY

In spite of numerous studies that have produced hundreds of recommendations, the Federal Government has been unable, and in many cases unwilling, to make any changes to the dual system where the FCC manages private use while the NTIA manages government use of spectrum resources. Even though the necessary coordination between the FCC and the NTIA/IRAC occurs in most cases, the potential for conflict still exists, and many of the long standing problems with spectrum management and utilization remain unresolved. What emerges from this look at the past is that the current system has performed well enough to keep the Government from being forced to make any substantive changes.

III. CURRENT U. S. SPECTRUM MANAGEMENT

While both the private sector and the Federal Government utilize the radio frequency spectrum, the processes that they use and the agencies they work with to obtain an assignment are different. This chapter will deal primarily with the spectrum management structure and processes that apply to a Federal Government agency request for spectrum, although the liaison and cooperative role that is played by the FCC will be discussed. Initially the discussion will address the highest level of national spectrum management and will work down to the level above the individual service components and unified commands.

A. FREQUENCY MANAGEMENT STRUCTURE

1. The NTIA

As was discussed in the previous chapter, the NTIA was created in 1978 within the Department of Commerce as the Executive branch agency principally responsible for the development and presentation of domestic and international telecommunications policy. The agency states its primary responsibilities and functions as:

- serving as the principal Executive branch adviser to the President on matters concerning telecommunications and information policy
- developing and presenting U.S. domestic and international telecommunications and information plans and policies, and coordinating U.S. Government positions with respect to international conferences and meetings, in consultation with the FCC and the Department of State
- prescribing policies for and managing Federal use of the radio frequency spectrum
- serving as the principal Federal telecommunications research and study center
- administering the Public Telecommunications Facility Program (PTFP). [Ref. 23: pp. 1-2]

During 1988, NTIA had approximately 300 employees, the majority of whom were primarily assigned to frequency management or to PTFP duties. In

January 1989, the agency was placed within the Department of Commerce Technology Administration, and the Assistant Secretary for Communications and Information now reports to the Under Secretary for Technology. The general organization for the NTIA is shown in Figure 1.

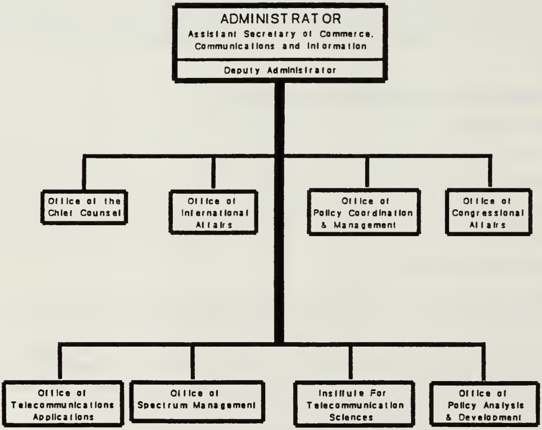

Figure 1. NTIA Organization

The principle staff element responsible for spectrum matters is the Office of Spectrum Management. Figure 2 depicts the organization of this office. Within this office there are four organizational elements involved with the spectrum. The Director of Spectrum Plans and Policies is concerned with both international and national spectrum policies. This office is the focus for all Government preparations for ITU Conferences. The Director acts as the IRAC chair, and the IRAC is responsible for providing support to this office. The Frequency Assignment and IRAC Administrative Support Division is concerned with the daily processing of frequency assignment requests and with the management of these assignments. The Spectrum Engineering and Analysis Division provides support to the Director in resolving electromagnetic compatibility problems and in the preparation of technical studies necessary for national and international spectrum management. The Computer Services Division is essentially a support element that provides computer operations and software support needed by the other divisions [Ref. 24: p. 124].

The Office of Spectrum Management was organized in this fashion to be well aligned with the four management program areas it has defined. These are: the Spectrum Plans and Policies Program, the Spectrum Management Program, the Spectrum Analysis Program, and the Frequency Assignment and Utilization Program.

The Spectrum Plans and Policies Program is concerned with the long-range plans for national use of the spectrum and is responsible for the development and maintenance of the National Table of Frequency Allocations. In addition, this program coordinates input and prepares U.S. positions and proposals for international conferences. Plans and policies that govern the use of the spectrum by the Federal Government are also developed by this program. They provide direction and guidance to the IRAC in its deliberations, and finally they are responsible for attempting to resolve conflicting requirements for spectrum space.

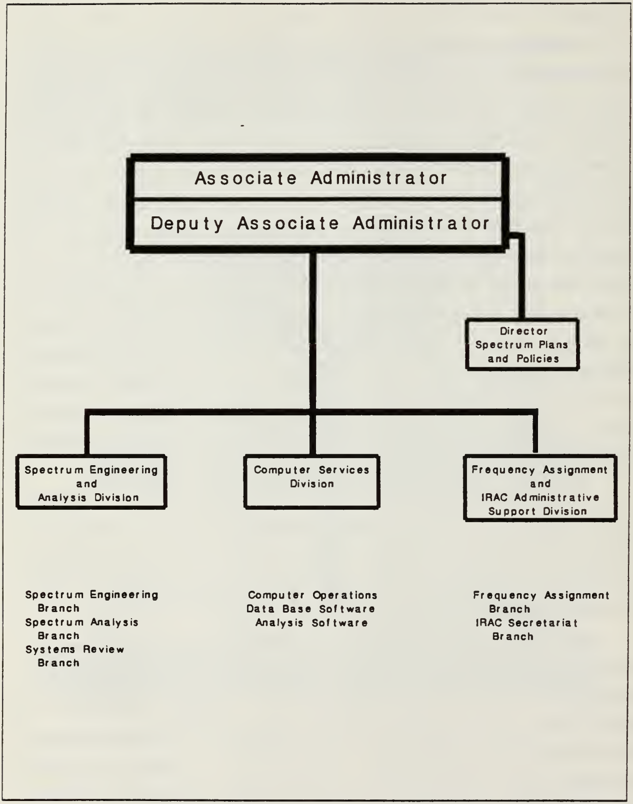

Figure 2. Office of Spectrum Management

The Spectrum Management Program is charged with providing technical and administrative support to the IRAC and with training for spectrum management personnel. The Spectrum Analysis Program conducts constant assessments of the frequency bands to determine if electromagnetic compatibility exists among current and proposed uses. In addition, they must review new system developments to decide how new communications equipment can be accomodated in the spectrum. They are the office responsible for providing input on management problems related to technical issues, and they develop new analysis techniques in an effort to resolve efficiency problems.

The Frequency Assignment and Utilization Program processes requests for and authorizes frequency assignments. It also maintains the databases concerning the use and management of the spectrum. Lastly, it is responsible for the monitoring of Federal Government spectrum use [Ref. 24: p. 126].

In addition to these components, the Office of Spectrum Management is assisted in the execution of its duties by two advisory bodies. The first of these is the Frequency Management Advisory Council. Originally established in 1965, the Council is to advise the Secretary of Commerce on matters concerning spectrum allocation and assignment that can improve the Federal Governments frequency management. Specifically, they review recommendations of the IRAC, review current electromagnetic compatibility problems, and provide input for U.S. positions and proposals at international conferences [Ref. 2: p. 1-12]. The second advisory body, and by far the more important, is the IRAC.

2. The IRAC

Having been originally established in 1922, the IRAC is the nation's longest standing body concerned with the Federal Government's use and management of the radio frequency spectrum and the principal advisory board to the NTIA. Membership consists of representatives from the following departments and agencies:

- Agriculture
- Air Force
- Army
- Coast Guard
- Commerce
- Energy
- Federal Aviation Administration
- Federal Emergency Management Agency
- General Services Administration
- Health and Human Services
- Interior
- Justice
- National Aeronautical and Space Administration
- National Science Foundation
- Navy
- State
- Treasury
- U.S. Information Agency
- U.S. Postal Service
- Veterans Administration

In addition, the FCC appoints a representative to serve as a liaison to the Committee. [Ref. 2: p. 1-6]

The IRAC has developed a permanent substructure, as shown in Figure 3, to assist in the execution of its duties. The Frequency Assignment Subcommittee is responsible for recommending assignment of frequencies for Government radio stations and for coordinating with the FCC on shared spectrum. The Spectrum Planning Subcommittee plans apportionment of the spectrum based on established and anticipated requirements. The Technical Subcommittee recommends standards for the improvement of spectrum utilization. and evaluates the potential of new spectrum optimization techniques.

The International Notification Group notifies the ITU of U.S. frequency assignments, and the Secretariat performs the administrative functions of the IRAC [Ref. 25: p. 2]. The FCC maintains a direct liaison role with all of the subcommittees, and its participation is the primary means of coordinating between Government and non-Government users of the spectrum.

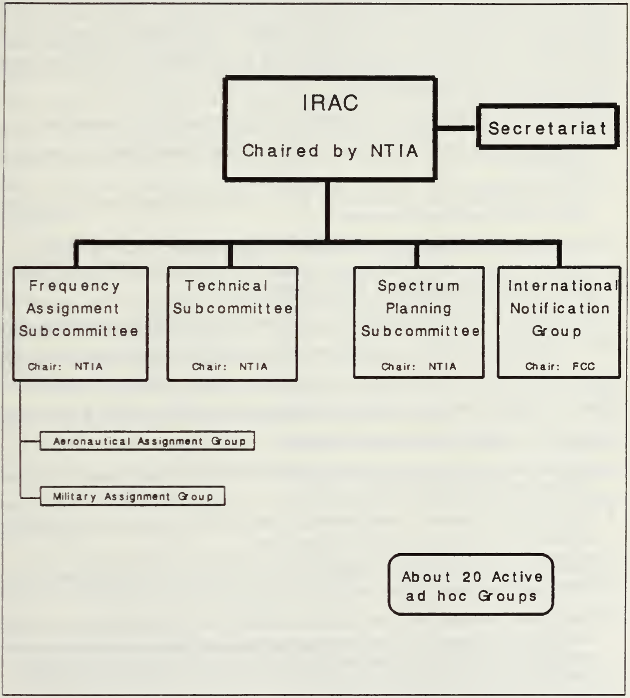

Figure 3. IRAC Structure

3. The Military Communications-Electronics Board (MCEB)

The lowest level structurally that will be addressed is the MCEB. This board is responsible for providing the Department of Defense (DOD) and the Joint Chiefs of Staff (JCS) with support in the coordination of communications and electronics activities among the Armed Forces. The Frequency Panel (FP) of the MCEB is the principal entity within the DOD concerned with spectrum management. It is responsible for:

- developing policies and procedures for DOD frequency management
- providing joint and interservice military frequency engineering and management
- providing frequency engineering and management assistance to other DOD components upon request
- maintaining the Frequency Resource Record System. [Ref. 25: pp. 2-3]

B. SPECTRUM MANAGEMENT PROCESSES

Having been presented with an overview of the primary agencies and bodies related to spectrum management for the Federal Government, now the specific processes that are used to make the system function must be reviewed. The NTIA has specified five separate functions that make up spectrum management decision processes. These are

- determining that spectrum is available before the Federal Government is authorized to purchase a new system
- engineering frequency assignments to ensure that systems will be compatible with existing and planned systems
- monitoring the use of the spectrum to guarantee that assignments are being used as authorized
- continually reassessing the actual, planned, and potential uses of the spectrum to determine probable areas of incompatibility, to determine the potential for intra- and inter-service sharing, and to determine possible expanded uses of the spectrum
- maintaining a timely and accurate record of all uses of the spectrum. [Ref. 24: pp. 127-128]

Implementation of the first function has been accomplished at all levels within the spectrum management structure. All equipment under consideration for development, purchase or lease by the military that will require the allocation of spectrum resources must gain initial approval from the Frequency Panel of the MCEB [Ref. 25: p. 2]. While the MCEB is not directly represented on the IRAC, the FP does supply the committee with information concerning DOD allocation requirements. Figure 4 shows the relationship of the MCEB and its FP to the other departments, agencies and committees involved. At the IRAC level, the proposal is reviewed again by the Spectrum Planning Subcommittee (SPS) for conformance with existing regulation and compatibility with other systems in the proposed band. Following a favorable review by the SPS, the NTIA will notify the requesting agency that spectrum space is available.

A multi-level review occurs in the MCEB and the IRAC to engineer frequency assignments so that interference does not occur. After a successful review by the MCEB the Frequency Assignment Subcommittee of the IRAC provides a secondary review to determine conformity with regulations and system compatibility. Only then will the NTIA authorize an assignment.

Monitoring the use of the spectrum is the responsibility of every authorized user. The NTIA performs this function through the use of a mobile van. The van monitors radio transmissions and determines channel usage. In addition, the NTIA does perform a limited number of inspections. Finally, the FAS must review all frequency assignments every five years to determine that the need still exists.

The fourth function combines technical, administrative and operational analysis to determine possible problem areas, and to develop the necessary means to correct them. A secondary goal is to establish policies and procedures that will allow for more intensive use of the available spectrum.

The fifth and final function is to maintain the data necessary to support the spectrum management processes. The NTIA and the MCEB both maintain databases used in frequency management. These are continually modified to

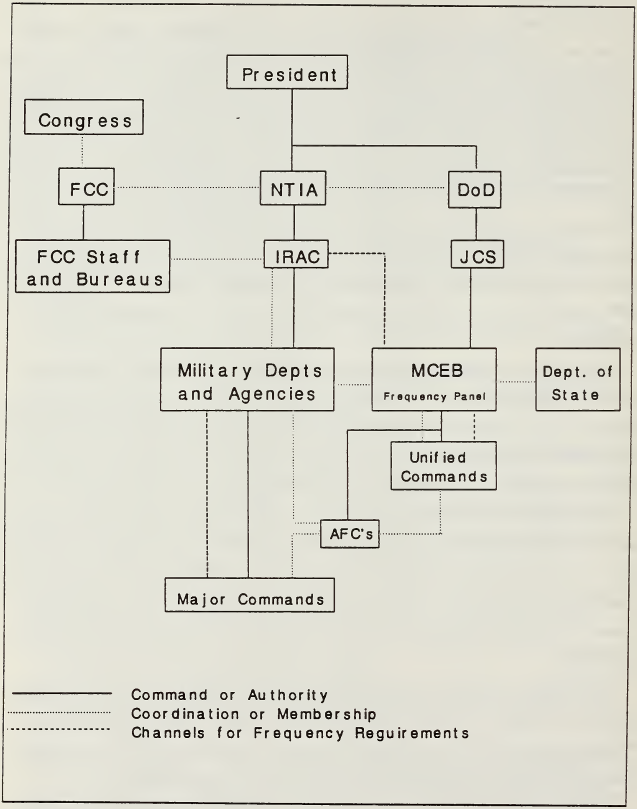

Figure 4. Frequency Management Channels

include more information about systems. and are updated to reflect current assignments.

C. SUMMARY

This chapter was intended to show both the structure that exists to manage the Federal Government's use of the spectrum and the functions that the respective agencies and boards perform. Combining this with an understanding of the national goals and objectives from Chapter One provides a fairly sound basis on which to evaluate the potential of different regulatory schemes to improve spectrum utilization.

IV. SPECTRUM MANAGEMENT ISSUES AND ALTERNATIVES

The earlier portion of this thesis has concentrated on a more descriptive approach to spectrum management as it is executed in the United States. The issues to be discussed now must be addressed in a more analytical fashion, as they deal with the primary areas of concern and provide alternative means of carrying out spectrum management. The majority of this discussion will again deal with national spectrum management; however, the increasing complexity of international spectrum matters will impact U.S. practices, so some discussion of international activity is necessary.

Interference is the root problem of all spectrum management issues. It may also be known as overcrowding or congestion, terms that imply an increasing possibility of interference: but by whatever name, it means that radio communications are obstructed, seriously degraded, or repeatedly interrupted by other signals possessing similar characteristics [Ref. 2 : p. 6-5]. It is important to note that current regulatory schemes are intended to be preventive, not corrective. For spectrum management to follow this guideline, it must address two general issues:

- What are the optimal allocation and assignment schemes? In other words, how does the regulatory body decide who gets spectrum and how much will they get?
- Secondly, once someone has been authorized to use a portion of the spectrum, what ownership rights does that person have over that band? Included in this is the level of protection offered by the regulating body of these rights.

The remainder of this chapter will look at the current methods of allocation used by United States, and the implicit and explicit ownership rights conferred upon the user. This will be followed by a discussion of alternative methods of allocating the spectrum and an assessment of their potential.

A. CURRENT U.S. SCHEMES

1. Allocation

The current allocation scheme in the U.S. is consistent with that of the ITU and is known by the term block allocation. This means that the spectrum is divided into blocks, and specific services are assigned to each block. The following example will serve to explain the principle. The UHF band (300-3000 MHz) has been one region of the spectrum where the congestion problem has been especially acute. Within the band is the block of frequencies from 512-608 MHz. This portion of the spectrum is reserved exclusively for the broadcast of UHF television signals [Ref. 2: p. 4-53]. In many parts of the country, much of this block of spectrum will be unused for the allocated service, but because of the block allocation technique, it is effectively removed from use by other services. This has resulted in significant portions of the usable spectrum being wasted.

Given that block allocation is not an efficient means of allocating the spectrum, the question arises as to why it was ever chosen, and why it is still the dominant method both internationally and domestically. In the words of one author,

> The existing allocation process can be considered as a form of a priori planning where a predetermined amount of resource is dedicated to a specific purpose. Like other a priori plans, it introduces rigidity while freeing administrations from the responsibility of providing dynamic management of the resource. [Ref. 26: p. 693]

In an earlier age, when usable spectrum was abundant and technical advances continued to "stretch" the spectrum, block allocation was adequate to meet the needs of the users. The principal advantages were the simplicity in managing the system and the equipment standardization that occured. In a period of signifcant congestion, block allocation does not have the flexibility of adapting to meet the current requirements. Twenty-one years ago, the Rostow Report critized the inflexibility of the system. Occasionly the spectrum management structure was able to respond to congestion problems, but only after lengthy negotiation and coordination [Ref. 9: p. 8-21].

It is puzzling that, given the inflexibility of this allocation scheme, it will be used for the forseeable future. NTIA released *NTIA Telecom 2000* in October 1988, outlining projected changes in telecommunications up to the year 2000 and Government initiatives to stay current and manage these changes. In that report they imply that the block allocation technique will continue to be used [Ref. 27: pp. 655-662] .

2. Assignment

The determination of frequency assignments must be based on some system that can determine relative value of services based on a set of standards considered valid by competing interests. It is also in the interest of the government that the standards be easy to measure and difficult to exaggerate. Current NTIA policy states that radio frequency assignments will generally occur in the following order:

- Frequencies used primarily, predominantly, and directly for national security and defense, for purposes which are vital to the safety of the Nation.
- Frequencies used primarily, predominantly,and directly to safeguard life and property in conditions of distress.
- Frequencies used primarily, predominantly, and directly to safeguard life and property in other than conditions of distress where other means of communication are not available.
- Frequencies used in scientific research and those used in services that have no adequate means of rapid communication, when such use is considered to be necessary or desirable in the national interest.
- Frequencies for all other purposes, the assignment of which must be judged upon the merits of the intended use. [Ref. 2: p. 2-4]

What emerges from these guidelines is that they lack clarity, are subject to substantial subjectivity in interpretation, and do not allow for objective comparisons of competing interests. In many respects it is a tribute to the people who are actively engaged in spectrum management for the Federal Government that, using these standards, they are able to routinely assign frequencies without causing significant bureaucratic infighting. On the other hand, it cannot be suprising that there have been numerous complaints over the Government's inability to provide justification for much of the spectrum it uses.

When assignments are made, the user generally assumes some ownership rights. The services are described in descending priority as primary, permitted, and secondary. When interference occurs, disputes tend to be resolved first by priority of service, and within a given priority level, by seniority regarding the date of frequency assignment. This method has developed over time and is used both internationally and nationally [Ref. 5: p. 48]. This practice of providing greater protection to the first user to receive assignments within a band has been an incentive for users to overstate their needs and to subsequently "bank" excess spectrum for the future [Ref. 9: p. 8-29].

B. ALTERNATIVE SCHEMES

Clearly the current management schemes have significant drawbacks that will become more acute as demand for the spectrum increases. Different methods of accomplishing the same objectives must be evaluated to see if they can provide both a more efficient distribution of spectrum resources and the incentives necessary so that users will compete for only that portion of the spectrum that they truly need. Many different schemes have been proposed, but there is one common thread among them: a greater reliance economic incentives to achieve optimal spectrum utilization.

1. Free Market Approach

This constitutes the most radical departure from the existing regulatory schemes. Under this scheme spectrum would be bought and sold, with the owner having the rights of emission, admission, use, and transferability. Emission rights constitute the owner's right to radiate within the frequency band that is owned. This would necessitate a three dimensional definition of the spectrum that includes frequency band size, time, and power. Admission rights concern the user's ability to refuse access to another user. Use rights means that the owner must be allowed to do anything legally permissable with that portion of the spectrum that is owned. Lastly, transferability rights include the owner's right to transfer emission and admission rights to others [Ref. 28: p. 5].

Conceptually, this scheme would result in an economically efficient distribution of the spectrum. There are practical factors that effectively rule out this alternative as an option. Since the spectrum fails to recognize national boundaries, it will be impossible for one nation to guarantee the ownership rights to a buyer. The nature of the spectrum is that while it may be used, it cannot be controlled. Secondly, if a free market approach is adopted, how would the government obtain spectrum resources? Should all spectrum be sold in a competitive market environment, or would spectrum be reserved, free of charge for use by the government? If all available spectrum space was to be sold, the government would not be able to guarantee that it could obtain the amount necessary to meet the public need. If spectrum was reserved for government use, there is no incentive for the government to be efficient in its use.

It is generally agreed that a free market scenario is unworkable, both practically and politically, but it does offer a new perspective from which to view the entire issue. This approach forces users to assign a monetary value to the spectrum they have or need, and provides them with economic incentives to be more efficient in their use of spectrum resources. It is interesting to consider, because the free market approach substantially reduces the government need to regulate spectrum use. There have been experiments proposed in the VHF and UHF television bands to evaluate how market forces would impact on the use of the spectrum [Ref. 28: p. 8].

2. Auctioning Rights

While similar to the free market in certain respects, auctioning would entail individuals bidding in interband and intraband contests for spectrum space. There are two possible approaches for such auctions with users receiving bandwidth or with users bidding on services (e.g., auctions of commercial FM services). Again, as in the free market approach, The owners would have significant rights over the spectrum or service that they had purchased. If spectrum were auctioned outright, the owners would have the ability to sublet or rent their space to other users. This system again uses

economic incentives to force users to place dollar values on the spectrum that they need. A variation on this would be to hold lotteries, where there is an established price and anyone willing to pay can enter the process.

The problems for the Federal Government's use of spectrum space are very much the same as under the previous alternative. Agencies will be unwilling to pay for a resource that has been free of cost. Additionally, there is no incentive to be efficient if the Government reserves portions of the spectrum for its exclusive use [Ref. 3: pp. 142-143].

3. User Fees

Using this scheme, charges would be applied to the users based on how much spectrum space they use. Spectrum use would be defined by time, geographic area, and bandwidth. A hybrid approach to these would be to assign user fees to services. Prices could be determined by any of the following methods:

- Established through interband auctions
- Estimated on what users are willing to pay rather than do without a unit of the resource
- Established at some flat rate. [Ref. 3: p. 86]

One of the attractive advantages of this approach is that the Federal Government could derive revenue from the user fees to pay for spectrum management. A variation of this basic concept is that only commmercial users would have to pay and the government would again be exempted. This eliminates the incentive by government users to declare their actual needs and to be efficient with spectrum space.

4. Shadow pricing

This alternative is dependent on being able to determine what users are willing to pay for an additional piece of spectrum space. If demand for the spectrum is high, the price for another unit would be high to drive demand down, and the converse would be true when demand is low. After some period of time. an equilbrium price would be established [Ref. 3: p. 86].

There are a number of hybrid approaches that amount to combinations of certain aspects of those already discussed. One final alternative is to try to

create administrative regulations used in spectrum management that attempt to simulate market forces, thereby providing incentives to users to again place some physical value on spectrum space.

C. ANALYSIS

Each of these alternatives has aspects that make them desirable to some segment of users. From a national viewpoint, the objective has been established that the intention of spectrum management is to make optimum use of the spectrum. This scheme should result in high-value applications receiving the needed space with low value users moving to other methods of transmission. One of the principal criticisms of the government's current frequency allocation is that there has been little documentation to validate the need or to evaluate whether only high value appplications are competing for space.

All of these proposals, with the exception of the proposal on new administrative methods, would involve removing the degree of control that the government has over the supply of spectrum. This means that for equilibrium to be established, the scheme must allow market forces the flexibility to react to changes. This is most clear in the free market approach, where the government is effectively on the sidelines. In the other approaches, some means other than pure market pressure is used to set the initial price for spectrum space. This could induce an unexpected demand initially, but over time if allowed to act as a market good, equilibrium again should be reached. Any one of these proposals, if properly implemented, should serve as an incentive to evaluate the level of spectrum used, while looking at alternative methods or new technology to be more efficient.

The central question is whether one of these methods could successfully be implemented by the Federal Government to manage the demand for its spectrum space. There are significant concerns that have little to do with spectrum space that affect this issue. No agency, be it government or private, wants to suddenly incur costs for the use of a resource that it has enjoyed previously free of charge. This would mean that any scheme where users would have to literally buy space or time would meet with considerable

opposition. A second issue is that, within the government, there is no guarantee that the agency with the greatest need for spectrum will have the means to pay for it. The Federal Government's decision criteria on how spectrum should be assigned do not include any way of quantifying how important the environment is when compared to national defense.

A second source of potential conflict is how spectrum would be redistributed under the plan. This means that any scheme resulting in an initial redistribution of spectrum space from the current distribution will be subject to substantial opposition. Realistically, the Government must recognize the level of capital investment that it has made in communications equipment which could be rendered useless by such a change. More practically, any change would virtually have to cede ownership to the current user. This eliminates the possibility of holding auctions for large blocks of spectrum. But, once ownership has been ceded to the current owner, there is little incentive for that owner to release it. unless there are incentives for such a move. This would mean that agencies that have portions of the spectrum with relatively low utilization rates should be penalized for low use. The primary problem with this approach is that the Federal Government uses a great deal of spectrum where dedicated channels exist for emergency purposes. Thus low utilization alone may not be sufficient to warrant penalties.

The bottom line is that while many of these alternatives provide interesting possibilities, there is little hope of seeing any widespread change in the current method of allocation. While both reports by the FCC and work by others indicate that there could be a substantial reduction in regulatory action by the Government if alternative management techniques were used in the private sector [Refs. 28, 3], there seems to be little movement towards a more market oriented approach in the private sector, and no indication that a new approach should be taken in the Government's own use of the spectrum.

This apparent lack of interest in the Federal Government changing its allocation scheme does not mean that it could not be improved. It is in this area that the concept of new administrative techniques is most promising. Current

procedures require that the NTIA make a finding that spectrum space is available prior to any work on a new system. This concept of frequency clearance should help to make better decisions [Ref. 3: p. 170]. There is a secondary problem of stockpiling that still exists. This can basically be defined as the setting aside of frequencies to prepare for growth and future uses. A secondary problem that has caused problems in the international arena is the stockpiling of frequencies that were once heavily used but now have only limited utilization [Ref. 29: p. 192]. The military has historically depended on public trust of its own evaluation of the need for space as sufficient. In a period of increasing demand for spectrum space, the military can expect a more difficult time obtaining resources if the requirements for such space are not well established.

D. SUMMARY

There is not sufficient domestic pressure on the current spectrum management processes to bring about any broad changes by either the NTIA or the FCC. There is enough spectrum available to meet the immediate and projected needs. The greatest potential threat comes from international forces that desire more spectrum space. Their concerns at the 1979 World Administrative Radio Conference resulted in the United States losing some of its stockpiled HF frequency space [Ref. 29]. This international emphasis makes it necessary for the United States to better document the stockpiling of frequencies and to work towards higher utilization rates on assigned frequencies that are only used sparingly. Only by increasing utilization can the Government demonstrate that the current frequencies assigned are needed. This means that current spectrum management procedures may have to be changed to encourage greater use of the spectrum, specifically in bands that have fallen into disuse. This may be the only way to guarantee the continued availability of those frequencies.

V. TECHNOLOGY AND THE RADIO FREQUENCY SPECTRUM

The developed countries have traditionally used technology as an ally in attempting to increase the size and capabilities of the usable spectrum. In the early part of this century, this meant that only a handful of nations were competing for that space. Generally, by the time crowding was a significant problem, technology had increased the size of the spectrum so that new frequencies could be exploited and the congestion tended to resolve itself. As time as passed, the situation has changed dramatically. That small group of nations, each wanting a part of the spectrum, now numbers over 160 [Ref. 27: p. 656]. A second problem is that the laws of physics apply to electromagnetic waves, and this creates physical limits on what can be expected of the usable spectrum. Below 10 KHz, antenna efficiency is so low that it makes this portion of the spectrum unusable for all but an extremely limited number of applications. Above 20 GHz, atmospheric attenuation is the limiting factor in an electron-based communications system. This means that for the overwhelming majority of electronic systems the effective operative spectrum is between 10 KHz - 20 GHz. The challenge becomes one of increasing the size of the usable spectrum within those bounds [Ref. 30: p. 12].

The existence of these physical limits does not alter the fact that the uses of the spectrum have changed significantly since the first wireless transmissions. The amount of equipment needed by today's military commander has grown and continues to grow. One estimate done by the British Army showed that the number of radios averaged one per hundred soldiers in World War I, but now averages one per soldier. Added to this are the concerns over modern elctronic warfare. The modern commander must be concerned with the jamming and intercept of friendly transmissions, while attempting to do the same to those of the opponent [Ref. 30: p. 13].

The questions that need to be answered are:

- What new tools have been created by technology to attack these problems?
- What is the impact of technologies' answers on spectrum utilization?

The traditional means used to improve utilization have been the exploitation of higher frequency bands, the employment of advanced modulation techniques, and the use of different polarization schemes. As was already discussed, new applications are being created faster than technology can respond to increase the size of the usable spectrum; therefore, frequency reuse techniques must rely heavily on the last two alternatives. This chapter will look at how the requirements for communications links in today's military environment is being met by technology, and how technology is helping.

A. ADVANCED MODULATION TECHNIQUES

The modern communications environment for the military commander demands that more links be established than ever before. This means that advanced modulation techniques must be used in conjunction with greater flexibility in providing multiple access in order to meet the demand. The main modulation schemes that are employed to allow for spectrum reuse are :

- Single Side Band
- Frequency Hopping
- Time Sequencing
- Direct Sequencing
- Hybrid spread spectrum forms

Many of these forms are used with one of the following multiple access schemes:

- Frequency Division Multiple Access
- Time Division Multiple Access
- Spread Spectrum Multiple Access

Each modulation and access technique will be briefly outlined to establish the nature and advantages of a given scheme.

1. Single Side Band (SSB)

This is not a new concept, since SSB is used extensively in the HF band. What has changed is that the technologies exist now to use SSB at frequencies up to 1 GHz. From a spectrum standpoint, in the VHF band, a SSB signal can operate in a bandwidth of 5 KHz as opposed to the traditional FM signal which requires a bandwidth of 25 KHz. SSB requires about the same peak power as an FM signal, but the average power radiated by the SSB transmitter is only six percent of the power radiated by its FM counterpart [Ref. 30: p. 14]. This makes interception and direction finding of the SSB signal much more difficult.

2. Frequency Hopping

Frequency hopping modulation systems utilize a large number of discrete frequencies are used in the transmission of a signal. The frequencies that are hopped to are spaced throughout the available band using a hopping pattern that is known only to the desired receiver. The rate of hopping and the hopping pattern can be changed to increase the difficulty in interception of the signal. A second advantage is that since the transmitter and receiver must be synchronized, the receiver will reject other signals that may be transmitted in the same frequency band. It may seem that spread spectrum systems would create more congestion since they require a greater bandwidth, but in actual use, a frequency hopping modulation scheme can actually reduce the possibility of harmful interference. [Refs. 31, 32]

3. Time Sequencing

Time sequencing or time hopping may be thought of as frequency hopping in the time domain. Instead of varying the carrier frequency, the transmitter varies the on and off keying times of the transmitter; thus, the signal appears to be random. This modulation scheme is used in conjunction with time division systems to reduce interference. One of the primary limitations of this scheme is that it is highly susceptible to jamming, since it operates at a single carrier frequency. [Refs. 31, 32]

4. Direct Sequencing

Direct sequence modulation uses a digital code sequence with a much higher rate than the information signal bandwidth to modulate the carrier [Ref. 33]. Typically the information to be transmitted is digitized and added to the spreading code which is then used to modulate the carrier. At the receiving end, the signal must be multiplied by a reference with the same spreading code for the information signal to be retrieved. Again by using the spreading technique the power envelope is much broader and lower, thereby increasing the difficulty in interception of the signal.

5. Hybrid techniques

Hybrid systems are especially prevalent in the military, and they are made up of a combination of the previous techniques. The most common combinations are:

- Simultaneous frequency hopping and direct sequence modulation
- Simultaneous time and frequency hopping
- Simultaneous time hopping and direct sequence modulation. [Ref. 31: p. 48]

These techniques have been used in an attempt to overcome some of the limitations that the indiviual systems have and to improve performance in multiple access environments.

6. Frequency Division Multiple Access (FDMA)

FDMA techniques involve the slicing of section of frequencies into a number of smaller bands, and allowing multiple users to transmit within those bands. Individual bandwidths would vary based on the information to be transmitted over a channel. This helps to improve utilization within the band, but in reality it is not much more than an extension of the current allocation scheme. With a given level of technology and type of signal, there is a limit to the number of times you can subdivide a frequency band.

7. Time Division Multiple Access (TDMA)

TDMA techniques allow the user to have access to the entire bandwidth, but only during a specified time slot. Again, this provides greater

access in a multiple user environment, but at there is a lower limit on the size of the time slice, below which the efficiency of the system is significantly reduced. While bits travel at the same rate for the entire system, as the number users increases, the time slice decreases to a point where the information rate of any individual receiver is significantly degraded. This limit is a function of the technology in use, the data rates required for the signals, and the characteristics of that region of the spectrum in which the system is designed to operate.

8. Spread Spectrum Multiple Access (SSMA)

This technique is also referred to as Code Division Multiple Access. Essentially, spread spectrum transmissions appear to be pseudorandom signals that are transmitted over several frequencies and several time intervals. Each user is assigned a unique code sequence, and all the signals share a common bandwidth. The principle advantages of SSMA are:

- It does not need timing coordination.
- It has simultaneous random access.
- Bandwidth is utilized more efficiently and no guard bands are necessary. [Ref. 34]

In all of these cases, by using a mutiple access scheme spectrum utilization is increased.

B. POLARIZATION SCHEMES

One of the principal factors that can influence the bandwidth needed for a given communications link is the characteristics of the antenna systems that are used. Early antenna design tended to focus on omni-directional antennae, which can be wasteful of spectrum. Newer designs have concentrated on creating narrow beams to allow greater frequency reuse over geographic regions. This has been especially successful in satellite communications. Additionally, different polarization schemes have been used to increase the possibilities for frequency reuse and for increasing flexibility in selecting portions of the spectrum in which to operate. Opposite hand circular and cross linear polarized antenna systems have the capacity to double the

available bandwidth under ideal conditions. The circularly polarized systems operate most effectively in the lower end of the microwave region, while linear polarization is better at the upper end. [Ref. 32: p. 22]

C. IMPLICATIONS FOR FREQUENCY MANAGEMENT

The capabilities of spread spectrum systems have resulted in their extensive use throughout all the services. The use of these systems has created a number of problems with the existing spectrum management process. Ideally, the services would like broad bands of spectrum available which they could use for spread spectrum systems. Since spread spectrum systems are so bandwidth intensive, it is only through the use of multiple access techniques that these systems are feasible in the modern battlefield environment. Broad bands of spectrum would allow for maximum flexibility in communications, and would further enhance the low probability of interception and detection of these systems. This idea of allocating large blocks of spectrum tends to run counter to the typical block allocation scheme as it has been used in the past. While a large band of spectrum may have been allocated for a specific service, it was generally the minimum amount necessary to support the current demand and projected growth for the service. The band was then subdivided into channels, with this being the amount of bandwidth that would eventually be assigned to a user. To guarantee that necessary flexibility is maintained, spread spectrum systems desire just the opposite. The modern battle scenario demands that there be an increased degree of flexibility.

D. ALTERNATIVES AND SUBSTITUTES

One of the traditional arguments for a more market-oriented spectrum management process is that it forces people to make a determination that signal transmission using the radio frequency spectrum is the most cost effective means available. Currently there are numerous substitutes for the spectrum, but the unique requirements of the military often limit those that can be considered. One promising area has been the growth in use of fiber optic cable. A distinct advantage of using fiber is that it possesses very large bandwiths, capable of extremely high rates of data transfer. The significant

limitation is that a physical link is required, thereby limiting the use of fiber to permanent or semi-permanent locations.

A second alternative that the military service have been exploiting is more of a procedural change than a technological one. There has been a significant effort to move more communications links from voice to data. By moving from voice to data, the information rate is reduced from 16 kilobits per second to 100 bits per second, generally. This reduced data rate allows for much more rugged communications, without a need to increase the bandwidth. The principal problem with this alternative is that users lose the immediacy and the impact associated with voice, and as a result this method has not received widespread attention outside military applications [Ref. 30: p. 14].

E. SUMMARY

In the past we have counted on technology to open up more of the spectrum for use. Now the operational requirements of the communications systems in use by the military demand that technology develop systems that use large amounts of bandwidth. The electronic battlefield is one of the primary reasons for multiple access, spread spectrum applications. Only through greater flexibility in how spectrum is used can these systems be implemented while maintaining compatibility. The use of low data rate systems provides some promise for better spectrum utilization, but it does not seem likely that users will ever eliminate the requirement for voice channels. The current spectrum management processes have been able to cope, partly due to strong military influence and partly due to the level of cooperation among the major interests. The problem that remains is, that as the military eats up more bandwidth, will the private sector and other government agencies allow them to continue without a strong challenge? Technology's answers are responding to the operational needs of the military services, and these answers do not always guarantee that bandwidth requirements will be kept at a minimum. The potential for conflict exists, and the present spectrum management system is not designed to function well unless there is a strong spirit of cooperation.

VI. SPECTRUM MANAGEMENT STRATEGY FORMULATION

It is clear from the previous portions of this study that the Armed Forces have gained significant influence in the allocation and assignment processes, and as a result they have received much of the available spectrum. This can be attributed not only to our national priorities, but also to the fact that the communications needs of the respective services were the catalysts for many of the breakthroughs in electronic communications. Comparatively, the DoD is in an enviable position regarding the amount of spectrum space assigned. This does not mean that it is unnecessary to develop a coordinated strategy regarding the present use and future plans for the spectrum. In fact nothing could be further from the truth. As the principal recipient of the Federal Government's spectrum resources, the services have the most to lose. Increased crowding in certain bands will naturally cause other users to evaluate alternative regions of the spectrum, and this makes the Armed Forces primary targets of users desiring greater amounts of spectrum space.

While the NTIA approved over 86.000 specific frequency assignment requests in 1988 [Ref. 23] and they acknowledge that national spectrum management is one of their primary responsibilities, they do not have a well articulated set of objectives on what they hope to achieve in spectrum efficiency or utilization. In *NTIA Telecom 2000*, their 1988 long range look at important telecommunications issues, spectrum management was relegated to a seven page appendix at the end of a report that was nearly 700 pages. It may well be that the size of the task is so vast that they are hesitant to commit resources to it, or that they perceive the risk associated with not having a strategy as low enough to be acceptable. The Armed Forces cannot afford to accept that risk. The electronic environment in which they operate demands that they have an articulated strategy that will support national security and treaty commitments.

This chapter will address both the process for formulating an effective spectrum management strategy for the military services and the most effective options that exist. The thrust of this strategy will be to support the joint needs of all the service components, therefore the terms Armed Forces strategy, DoD strategy, and joint service strategy will be used interchangeably.

A. DEFINITION OF STRATEGY

To construct a coherent strategy, first there must be a clear understanding of what strategy is. Especially in the military environment, there is a great degree of confusion over what constitutes strategy versus what constitutes tactics. James Brian Quinn has defined a strategy to be:

> ...the pattern or plan that integrate's an organization's major goals, policies, and action sequences into a coherent whole. A well-formulated strategy helps to marshall and allocate an organization's resources into a unique and viable postures based on its relative internal competencies and shortcomings, anticipated changes in the environment, and contingent moves by intelligent opponents. [Ref. 35]

This differs from tactics in that tactics tend to emphasize a more adaptive response in an action-reaction type of situation. Strategy is focussed on long term achievement of organizational objectives.

B. STRATEGIC GOALS

Once there is a clear understanding of what a strategy is, this leads directly to the question: What are the strategic goals and objectives of the Armed Forces as they concern the management of spectrum resources? This can best be understood by looking at the functions and the systems that must be supported. These include:

- Command and control over all forces. This includes everything from hand-held tranceivers used by foot soldiers to hardened command links that communicate with strategic forces.
- Weapons control systems. These include a variety of radars, voice and data links.
- Active and passive surveillance systems.
- Electronic navigation systems. [Ref. 36: p. 17.3.1]

Translating these into spectrum management objectives becomes an exercise in technical as well as administrative expertise. The technical concerns are associated with ensuring the electromagnetic compatibility of existing systems with proposed systems, and with developing new technological answers to improve utilization of assigned bandwidths. The administrative part of this is not so straightforward. It involves the translation of engineering and operational requirements into new frequency assignments. It also means the protection of existing assignments from encroachment by other users. It also means working to guarantee that bands that are currently not in demand are structured for flexibility for future use [Ref. 36: p. 17.3.3].

A final preliminary step in the formulation of any strategy is the assessment of the risk involved and the consequences of a failure to pursue the correct strategy. For the DoD, the consequences relating to the failure to adequately protect spectrum resources can be summarized as follows:

- The potential for accelerated obsolescence of existing equipment.
- Limitations on the range of communications systems that can impact on the geographic deployment of forces.
- Increasing costs of electronic communications equipment. If spectrum rights are not adequately protected, there will be additional costs incurred to replace obsolete systems and to keep system perfomance at acceptable levels in an incompatible environment.
- The performance of surveillance and weapons systems that rely on the radio frequency spectrum could be significantly degraded.
- Increased interference will create chaos in communication and data links. [Ref. 36: p. 17.3.1]

To meet its responsibilities and commitments, the services must have electronic communications capabilities that are secure, jam-resistant, covert, and available under all conditions.

C. STRATEGIC ENVIRONMENT

The formulation of any strategy must include an assessment of the environmental factors that influence the system. Having already looked at the internal environment in addressing the current regulatory structure for the

Federal Government, we must look at those factors external to the system that can influence spectrum management issues. In discussing these outside forces, it is impossible to formulate an effective strategy without looking at international developments in spectrum management. This appears to be the principal threat to DoD spectrum resources.

Historically, technical factors were the primary consideration in international allocation decisions. At the most recent World Administrative Radio Conference (WARC) this ceased to be true. Many nations are now challenging the traditional means of allocating frequencies and are advancing non-technical criteria to use along with technical concerns in making decisions. Lesser developed nations have used their voting strength in the international arena of the ITU to improve their respective positions regarding spectrum resources. In the late 1970's, there was considerable concern in preparing for WARC 79 that the United States could face a serious threat to "reliable spectrum management and the prospect of inadequate allocations for US requirements" [Ref. 37: p. 313].

While the United States came away from WARC without significant damage, areas of concern emerged that must be addressed in the DoD strategy.

- The lesser developed countries are heavily dependent on the HF portion of the spectrum, and they are competing directly with U.S. military needs in this band. This is complicated by a decrease in utilization of this frequency band by the services.
- Developing nations are increasingly obsessed with obtaining allocations in bands that they cannot presently exploit in an effort to guarantee them some spectrum space in the higher bands.
- Many countries refuse to recognize or appreciate the requirements and investments in advanced systems, specifically U.S. military radar, and are competing against these systems for spectrum space. [Refs. 38,29]

In the international environment, there has been an exponential growth in the number of competitors for spectrum resources, and the power of the developing countries in the ITU forum cannot be dismissed. Unfortunately, a WARC only occurs once every twenty years. Many of the actual changes are considered in smaller meetings that take place during the intervening periods. It is

imperative that the United States maintain a high level of concern at the interim meetings in order to protect thes vital resources. Unfortunately, this has not happened. Senator Harrison Schmitt said in a 1982 speech that

> US approaches that rely on our technical expertise and ad hoc policy development will eventually ensure that the US will end up in the loser column. [Ref. 39]

The DoD must adopt an aggressive strategy in pursuing US requirements in the international arena, and must solicit the support of our allies to guarantee that exisiting systems are not adversely affected and that sufficient flexibility is built in for future systems.

D. COMPARATIVE STRENGTHS

In the national spectrum management process and in the ability to impact on U.S. positions in international conferences, the Armed Forces have been able to greatly affect the specturm resources allocated for their needs. It has long been contended that the military has an inordinate amount of influence on the IRAC, and between that body and the MCEB, the miltary has created a permanent infrastructure that is capable of making existing processes work to its advantage. It is interesting to note that, in an era when DoD is placing a greater emphasis on the services planning and executing joint service operations, the individual service components still represent their own interests on the IRAC and that the DoD does not have any direct representation on the committee.

A second factor that relates to the relative strength of the services in the national spectrum management process is the recognition of the level of investment by the Armed Forces in electronic communications. One estimate at the beginning of this decade placed the level of annual investment at over $10 billion [Ref. 36: p. 17.3.1]. Clearly at the national level, this makes the DoD by far the heaviest investor in these systems and has further added to their ability to influence the processes in their favor.

E. COMPARATIVE WEAKNESSES

Relative to their competitors in the Federal Government, the Armed Forces do not show any comparative weaknesses. They have been weak, though, in creating changes to the existing system that would increase flexibility. A specific example of this is the congestion in th UHF band. With the increases in land mobile, mobile satellite, and fixed satellite communications, there has been an increasing demand for space in the UHF band. Repeated attempts have been unsuccessful in reassigning bandwidth that is currently allocated for UHF television [Ref. 36: p. 17.3.3]. This weakness is more a result of the inability of the current allocation scheme to be responsive to the changing needs of the users, but it is a limitation that the services must contend with in competing for spectrum.

A second weakness of the national spectrum management system which adversely impacts the DoD is that the division of responsibilities among various agencies which manage the spectrum creates problems in defining national goals when preparing for international conferences. For the last WARC, there were ten separate committees and working groups organized to consider and prepare U.S. proposals, options and alternatives. Six of these groups dealt with the space WARC [Ref. 37: p. 314]. This makes it extremely difficult to establish clear policy objectives that will translate into proposals. The different groups reflect different users and each one has its own set of priorities.

F. PROPOSED STRATEGY

The historical development of national spectrum management was strongly influenced by the military, with that influence being especially pronounced since the beginnning of World War II. The ability of the military services to use the existing regulations to best advantage was a function of both the Government's recognition of its national security needs and the services' ability to establish an effective infrastructure that provided the technical and administrative talents needed.

All this has made the DoD the number one "owner" of spectrum space within the Federal Government, and strategy becomes more a problem of

maintaining the influence and control that one has over the system and not one of taking any radical departure from the present course. It is clearly in the best interests of the services that they maintain the degree of influence that they have on the IRAC. As the principal body involved with the day to day management of the spectrum, the IRAC will continue to be a powerful committee.

The MCEB must continue to serve as a focal point for the services to resolve electromagnetic compatibility problems. Internal resolution of these problems limits the influence of other government agencies on bandwidth that is currently assigned to or is needed by the Armed Forces. The MCEB also acts as a joint service body of experts to investigate and validate the need for additional spectrum space. This helps to ensure that spectrum requirements are amply justified.

What emerges in the final analysis is that the Armed Forces are best served if the existing system of allocation and assignment remains in place. There still remains a problem of increasing flexibility in the process to accomodate the rapidly changing requirements of the services. The strategy must encompass policy, procedures and systems.

The DoD must work with other agencies to articulate a more specific policy for the management of the radio frequency spectrum. This policy must weigh current demand and projected changes in an attempt to determine the future availability of spectrum resources. This effort must be conducted jointly by Government and non-Government users to provide greater focus on potential problems and some guidance to the research scientists, whose work may provide some relief through advances in technology. This policy should also serve as the foundation for the development of U.S. proposals and positions at international conferences. In 1979, the Congressional Office of Technology Assessment concluded that there must be fundamental changes in the making of policy or the long term international telecommunications interests would be at risk [Ref. 40]. Only through the development of overall policy objectives can

the U.S. hope to compete successfully in the increasingly political ITU environment.

The joint service strategy must encourage procedural changes that will improve utilization of the spectrum. This means that the shift from wide band voice systems to rugged, low rate data communications should continue. The emphasis on the transmission of data instead of voice can result in significant savings in bandwidth. A second procedural recommendation is to work at improved utilization in bands where the services have existing assignments but historically low utilization rates. This will mean an increased emphasis on transmission in the HF band, which will meet with resistance due to the reduction in signal quality. The positive side effect is that increased utilization in other bands will help reduce the serious congestion problems in the UHF band.

Finally, the military must look at current and future systems, and continue to push technology to the limit in providing new and unique ways of increasing the size of the usable spectrum. A comprehensive look at operational requirements and technical possibilities will result in more effective use of the spectrum. This includes a continuing evaluation of the advances in terrestrial bandwidth (e.g., fiber optic cable) that can serve as substitutes for the radio frequency spectrum. A periodic assessment of these advances will support a better decision process when new systems are considered to meet the ever-changing roles and responsibilities of the services.

This emphasis on policy, procedures and systems within the existing national spectrum management regulatory framework is the Armed Forces' best strategy to ensure that the spectrum resources they need to meet their operational commitments will be allocated and assigned.

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